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Expanding the port area using contaminated dredged sediments

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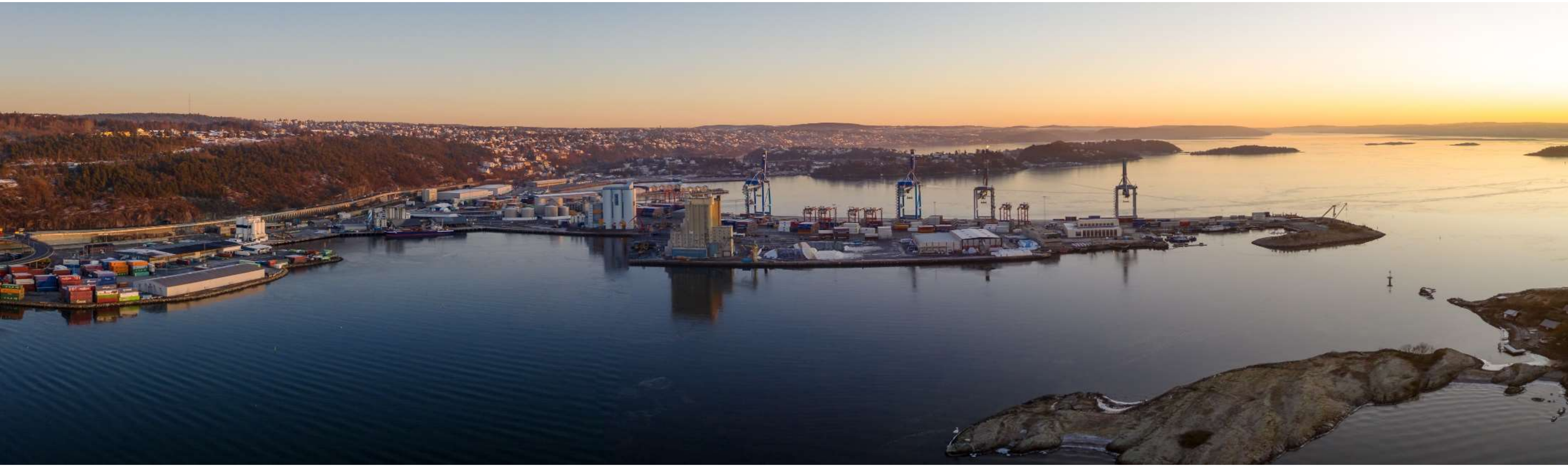
- Norways biggest container terminal
- Import terminal for fuel
- Import/eksport of cement
- Carimport
- Grain and salt storage
- Concrete fabric
- Transshipment terminal for containere
- Storage and shipping of captured CO_2 (coming)



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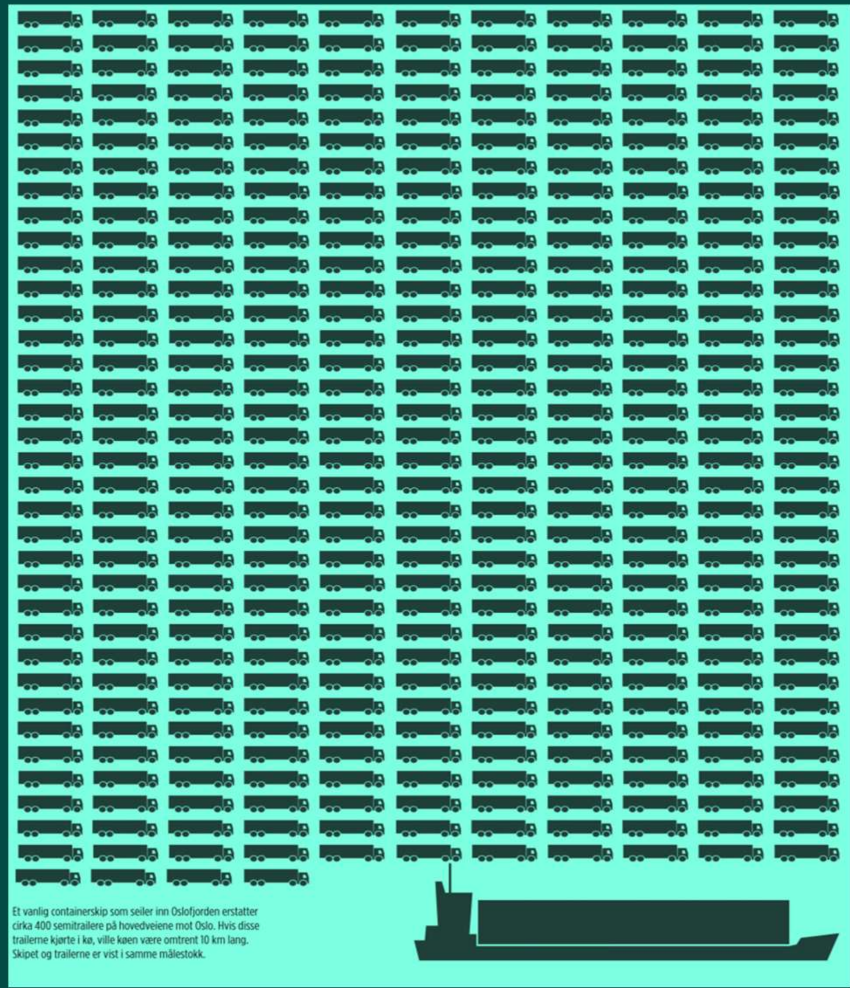
One average ship → 400 semi-trailers from Europe to Norway → 10 km queue



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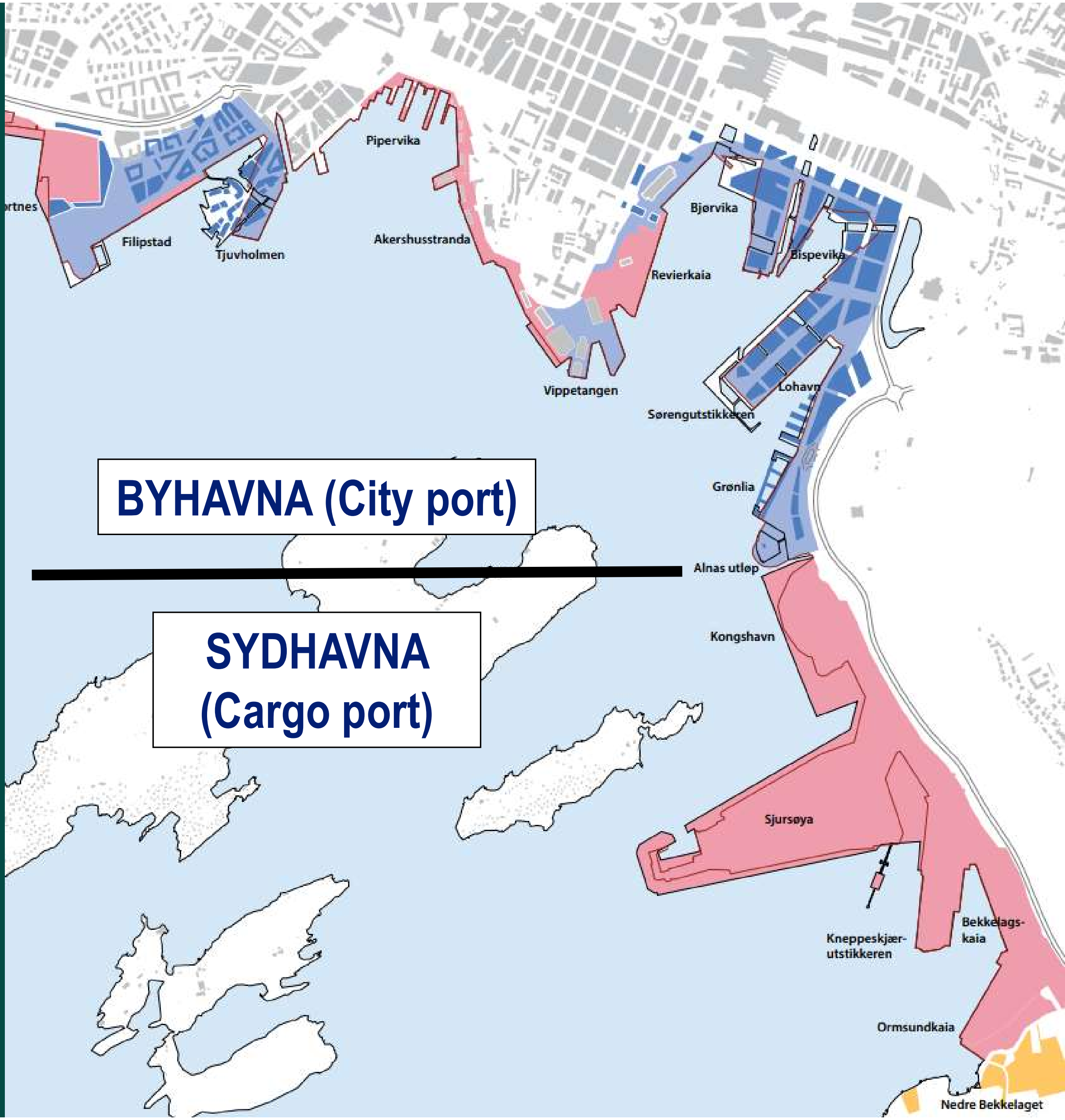
A large port in a small area



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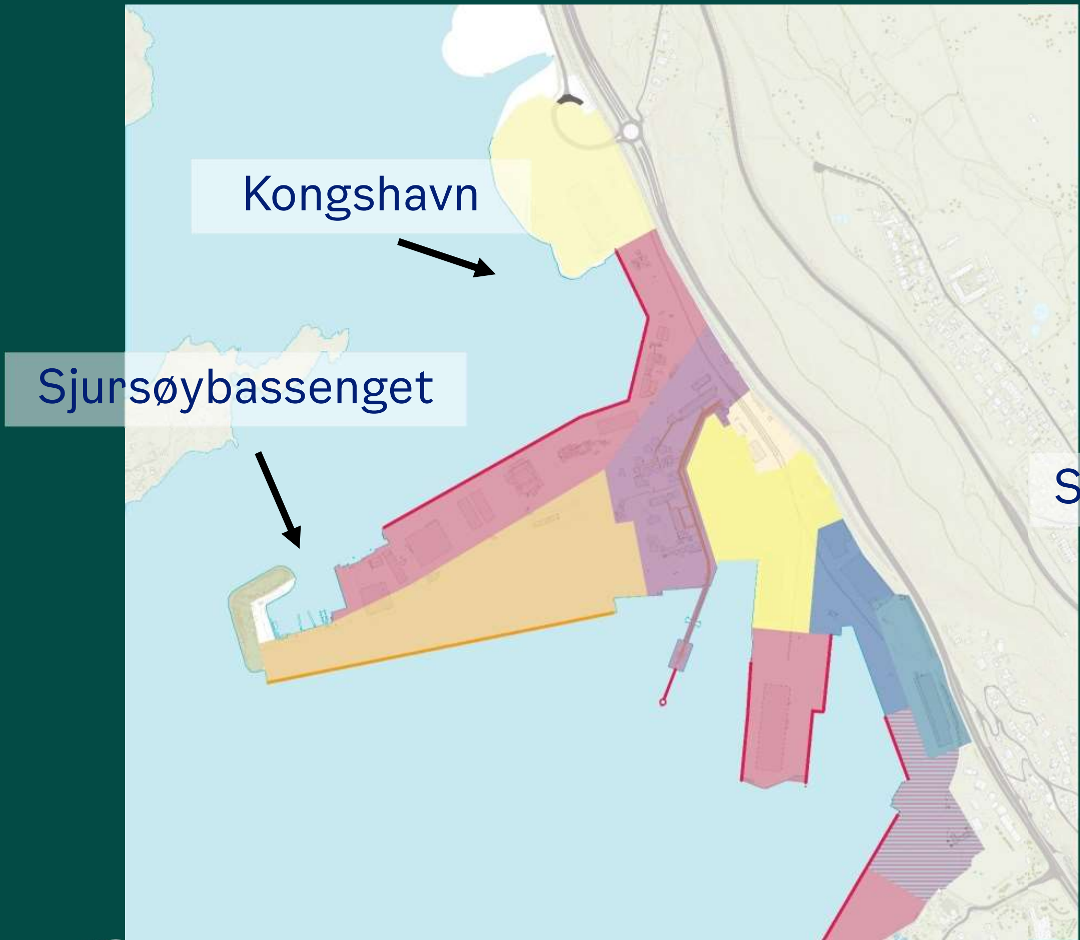

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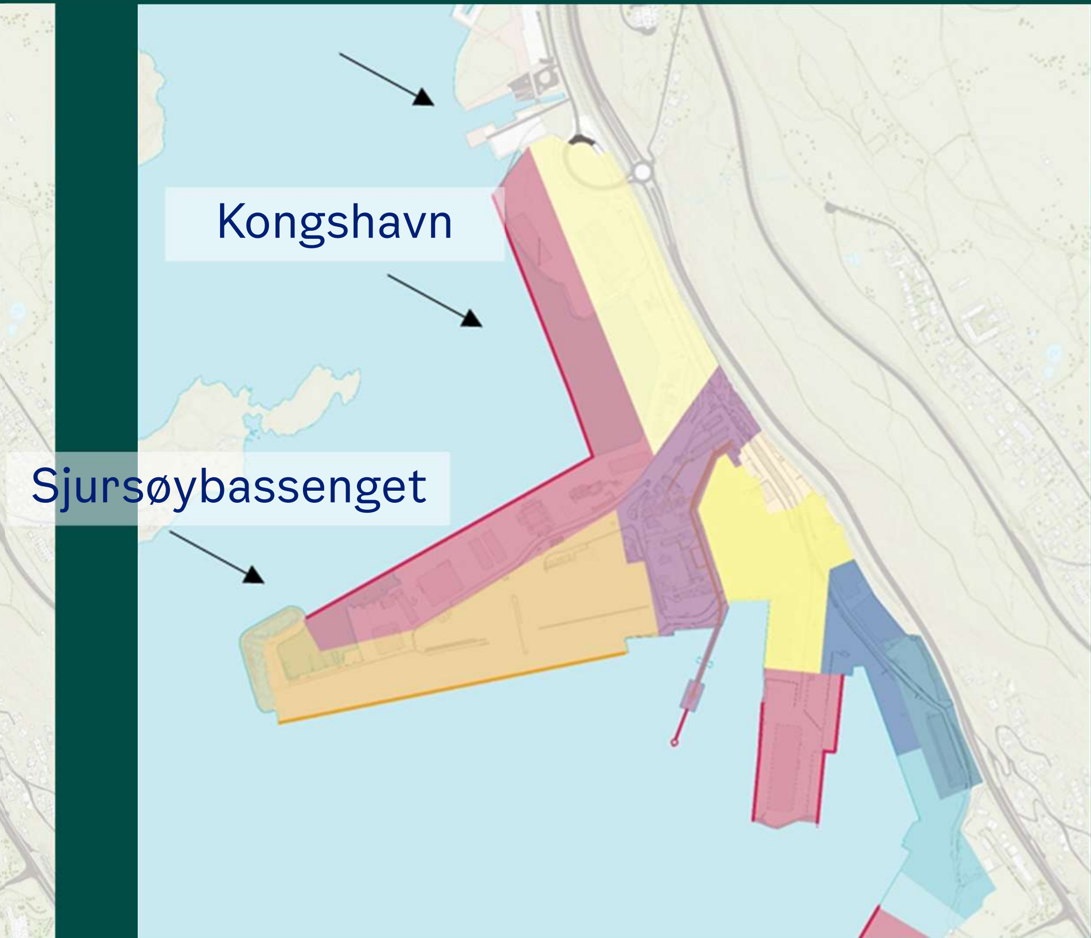


Purpose of project

- Port of Oslo need to develop new port area
- This necessitates dredging to attain a sailing depth of -12m

Excess mass

- Estimated total need for dredging: 180 000 m^3
- Estimated contaminated sediments: 105 000 m^3

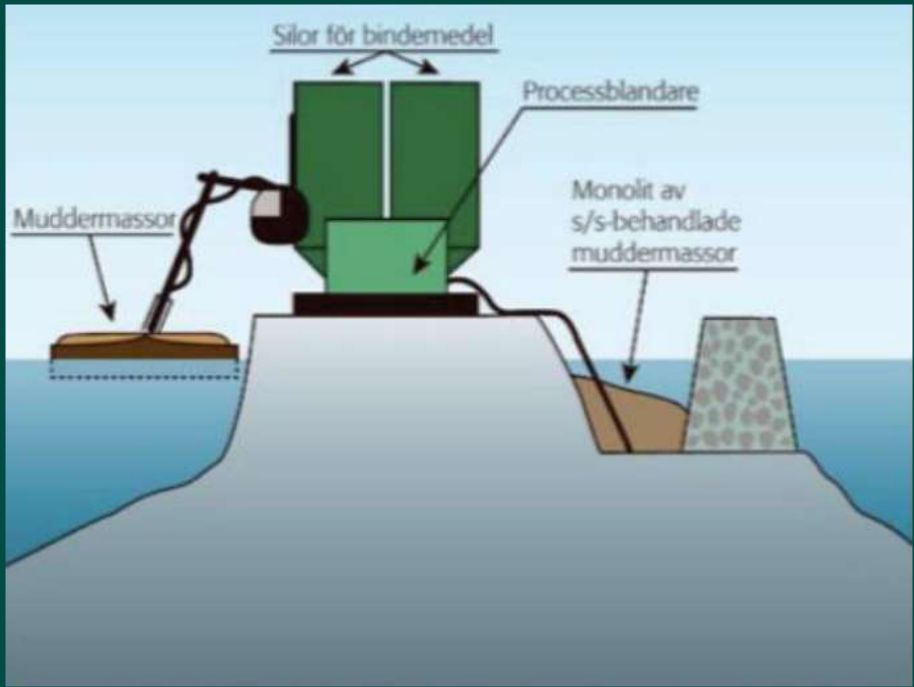
Alternative methods for handling dredged sediments

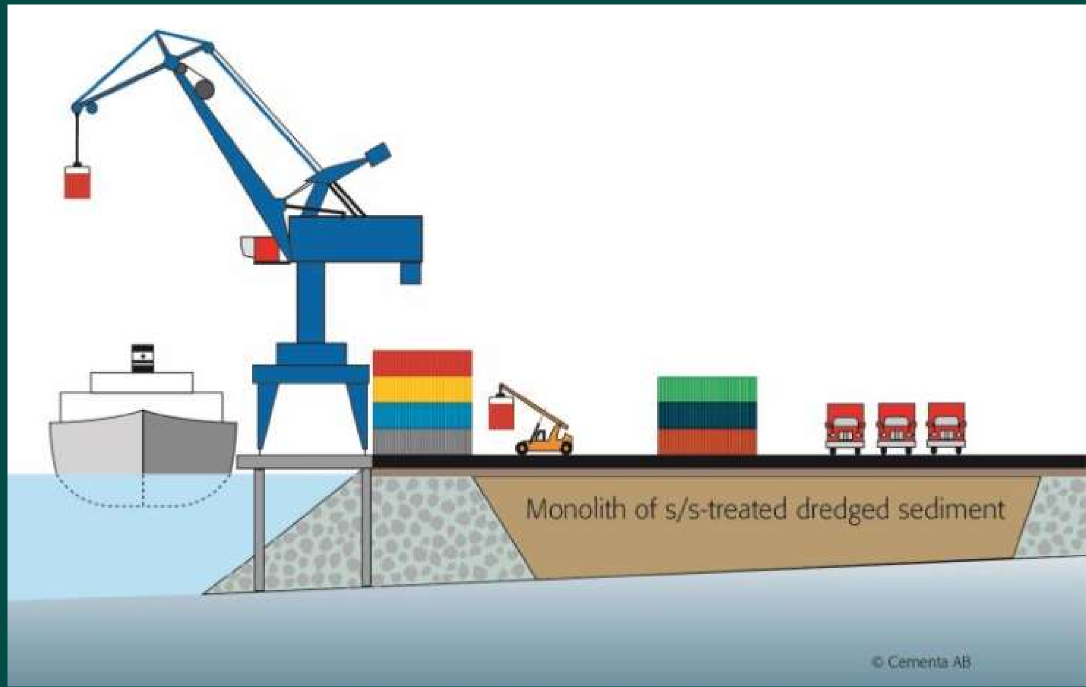
- Landfill
- Deep water landfill
- Shoreline landfill
- Stabilization and solidification

This work have been conducted by

- Oslo Havn (supervisor)
  - Hege Stusvik, Erlend Pehrson, Heidi Neilsson
- Norconsult
- Universitetet i Lund
- Waste Management AS
- Göteborgs Havn
- Skei Mining Consultant

Stabilization and solidification – the method





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Previous experience with the method in the Nordics

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Port of Oslos project for learning

- Collecting and analyzing sediment samples
- Analyzing the contamination degree of the sediments to classify the contamination at the sea bed
- Laboratory experiments on stabilization and solidification (STSO) of sediments
- Geotechnical assessment of locations where the masses could potentially be utilized
- Environmental impact assessment
- Economics

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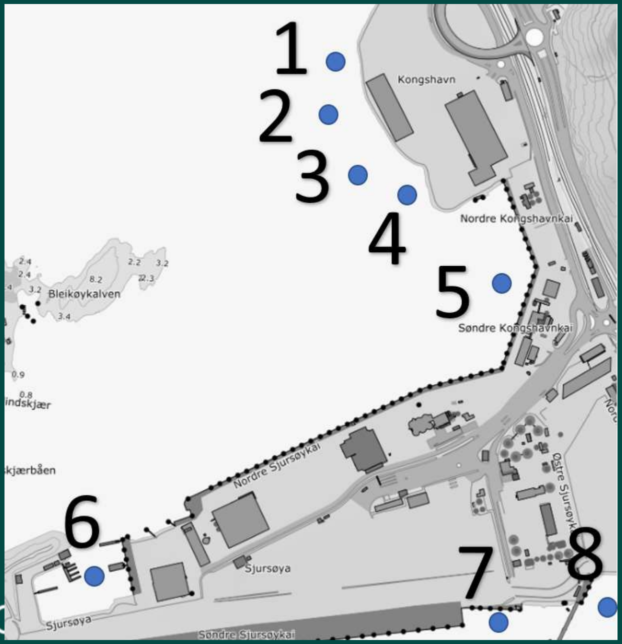
Extraction of sample material

- In test points 1-6 and 8, the samples consist of 5 sub-samples, totaling 20 liters. Additionally, besides core samples, an environmental sample of the seabed was taken.
- In point 7, core samples couldn't be obtained due to hard sediment.



Punkt	Visuell vurdering av prøver
1	Kongshavn nord, 5,7m dyp. Silt mudder, oljeklumper, mye skjell.
2	Kongshavn nord, 5,6m dyp. Mer leire enn i punkt 1, litt skjell, ikke oljeklumper.
3	Kongshavn sør, 7,4m dyp. Mer leire enn nord, lite skjell, mulig oljeklumper på 25 cm dyp.
4	Kongshavn sør, 9m dyp. Leire uten stein, med skjell.
5	Utenfor Unicon, 8m dyp. Blanding av lyse sandige sedimenter og mørkere leire.
6	Sjursøybassenget, 7m dyp. Sandige sedimenter.
7	Øst for Tankskiputstikkeren, 11,3m dyp. Steinfylling. Forsøkte å ta en liten prøve av skjellsand fremfor kaifront på 8,m dyp. Ikke nok materiale til STSO prøve.
8	Vest for Tankskiputstikkeren, 11m dyp. Prøve tatt i framkant av steinfylling. Siltige masser med stein.

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Results – Environmental tests

Tilstandsklasse	I	II	III	IV	V
Beskrivelse av tilstand	Bakgrunn	God	Moderat	Dårlig	Svært dårlig
Betingelser	Bakgrunnsnivå	Ingen toksiske effekter	Kroniske effekter ved langtids eksponering	Akutt toksiske effekter ved korttids eksponering	Omfattende akutt-toksiske effekter

	Prøvemerking	Kongshavn 1-2	Kongshavn 3-4	Kongshavn 5	Kongshavn 6	Kongshavn 8
Arsen (As)	mg/kg TS	13	10	9	7,5	13
Bly (Pb)	mg/kg TS	47	34	38	45	100
Kadmium (Cd)	mg/kg TS	0,5	0,2	0,32	0,1	0,86
Kobber (Cu)	mg/kg TS	90	31	88	50	100
Krom (Cr)	mg/kg TS	47	43	45	37	52
Kvikksølv (Hg)	mg/kg TS	0,365	0,17	0,174	0,317	0,574
Nikkel (Ni)	mg/kg TS	41	38	30	26	50
Sink (Zn)	mg/kg TS	200	140	140	180	350
PCB 28	mg/kg TS	0,0054	< 0,00050	< 0,00053	0,0017	0,0063
PCB 52	mg/kg TS	0,019	0,00061	< 0,00053	0,0059	0,017
PCB 101	mg/kg TS	0,014	< 0,00050	< 0,00053	0,0026	0,015
PCB 118	mg/kg TS	0,0098	< 0,00050	< 0,00053	0,0031	0,012
PCB 153	mg/kg TS	0,02	0,00063	0,0011	0,0033	0,012
PCB 138	mg/kg TS	0,02	0,00063	0,0011	0,0033	0,012
PCB 180	mg/kg TS	0,013	< 0,00050	0,0007	0,0022	0,0071
Sum 7 PCB	mg/kg TS	0,1	0,0019	0,0029	0,022	0,081
Naftalen	mg/kg TS	0,27	0,023	0,019	0,018	0,12
Acenaftylen	mg/kg TS	0,11	< 0,010	0,011	0,016	0,096
Acenaften	mg/kg TS	0,075	< 0,010	< 0,011	< 0,010	0,038
Fluoren	mg/kg TS	0,1	< 0,010	0,013	0,012	0,07
Fenantren	mg/kg TS	0,46	0,033	0,096	0,084	0,42
Antracen	mg/kg TS	0,23	0,012	0,023	0,031	0,17
Fluoranten	mg/kg TS	0,82	0,078	0,16	0,19	1,2
Pyren	mg/kg TS	1,8	0,099	0,22	0,19	1,3
Benzo[a]antracen	mg/kg TS	0,47	0,031	0,035	0,1	0,57
Krysen/Trifenylen	mg/kg TS	0,31	0,026	0,038	0,075	0,52
Benzo[b]fluoranten	mg/kg TS	1,6	0,078	0,12	0,21	1,3
Benzo[k]fluoranten	mg/kg TS	0,54	0,027	0,04	0,074	0,39
Benzo[a]pyren	mg/kg TS	1,1	0,042	0,067	0,12	0,74
Indeno[1,2,3-cd] pyren	mg/kg TS	0,67	0,02	0,045	0,11	0,53
Dibenzo[a,h]antracen	mg/kg TS	0,14	< 0,010	< 0,011	0,021	0,13
Benzo[ghi]perylen	mg/kg TS	0,69	0,031	0,053	0,12	0,54
Sum PAH (16) EPA	mg/kg TS	9,4	0,5	0,94	1,4	8,1
Tributyltinn (TBT)	µg/kg tv	90	6,9	3,2	92	14
Dibutyltinn (DBT)	µg/kg tv	100	9	<2,5	74	16

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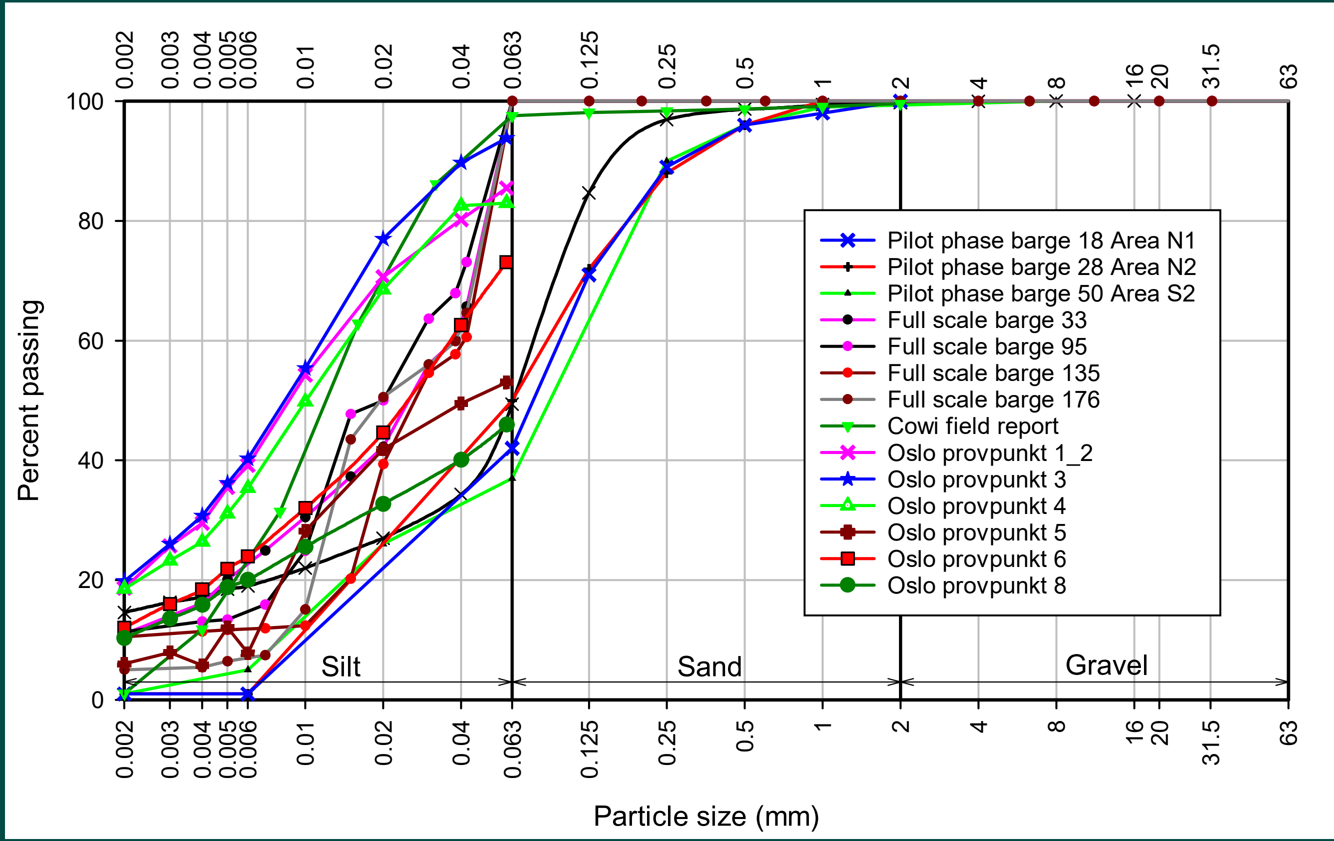
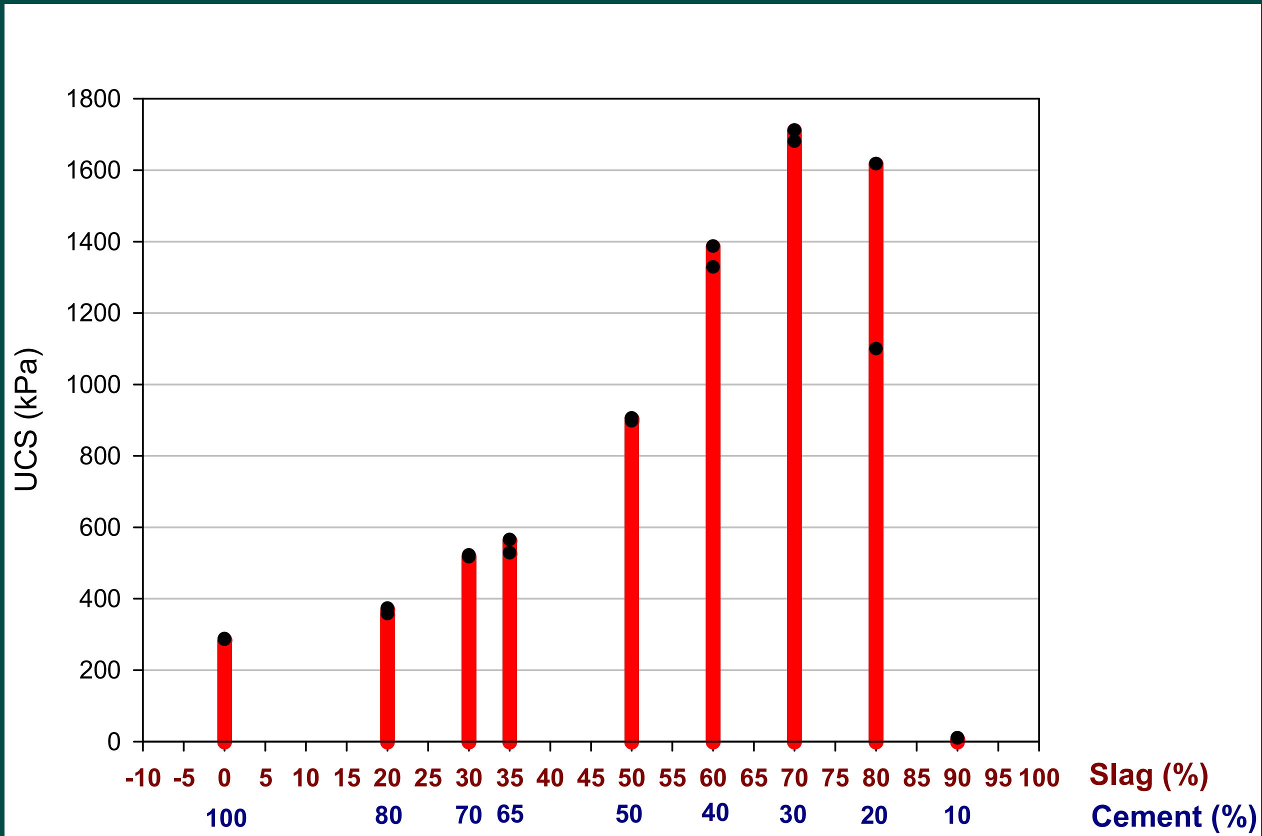
Results – Grain distribution

- Mainly silt and clay



Results – Mechanical strength



Mechanical strength depending on the distribution of cement/slag

Results - Permeability

- The treated mud mass achieved very low values for permeability
- For comparison: Requirements for density for waste landfills are 1 x 10^-9 m/s

Prøvenummer	Permeabilitet (m/s)
1_2_5	1,5 x 10 -9
3_5	1,0 x 10 -9
4_1	1,2 x 10 -9
5_4	4,8 x 10 -10
6_5	3,0 x 10 -9
8_5	1,5 x 10 -9

- Since the permeability is so low, one can assume that any potential contamination would only leak from the surface of the stabilized masses and not from within the volume.

Results – Recipe

- The table presents the mixture that yields the highest mechanical strength

Bindemiddel	30% sement / 70% slagg
Innblandingsmengde	120kg bindemiddel pr. m3 sediment
Vann/bindemiddelforhold	5 (vbt: vekt vann/vekt bindemiddel)
Type sement	CEM I (CEM 197-1)
Type slagg	Granulert masovns-slagg fra stålindustrien (EN 15167-1)

Egenskap	**Verdi, gjennomsnitt**	**Vbt, (vann/bindemiddel)**
Styrke	869 kPa	5
Permeabilitet	1,5 x 10 -9 m/s	5

Results – Leaching, method: shaking

- The results in the table indicate the amount of pollution leaking from crushed material when agitated in water.
- Red figures exceed the requirement for inert waste.

Parameter	*L/S = 10 l/kg ved ristetest med*	
	partikkelstørrelse < 4 mm	
	mg/kg tørrstoff	*Resultat*
Arsen (As)	0,5	0,029
Barium (Ba)	20	1,06
Kadmium (Cd)	0,04	<0,0005
Krom (Cr) totalt	0,5	0,0379
Kobber (Cu)	2	6,9
Kvikksølv (Hg)	0,01	<0,0002
Molybden (Mo)	0,5	0,527
Nikkel (Ni)	0,4	0,814
Bly (Pb)	0,5	0,0055
Antimon (Sb)	0,06	0,0083
Selen (Se)	0,1	<0,03
Sink (Zn)	4	<0,02
PCB7	1	0,000257
PAH16	20	0,02
Benso(a)pyren	2	0,0034

Results – Leaching, method: monolitt

- Leaching from the surface of solid material.

Forurensning	**Lekkasje pr m2 (mg/m2/år)**	**Lekkasje dersom overflate mot sjøvann er 650 m2 (g/år)**
Arsen	0,9	0,6
Nikkel	2,8	1,8
Sum PAH	0,05	0,03
TBT	0,0006	0,0004

Summary

- STSO makes it possible to assign value to the contaminated mud masses, utilizing a product that is typically considered waste.
- It is possible to achieve a mechanical strength that exceeds the requirement for a standard quay.
- By using local materials, there will be no need to transport external fill materials for filling port areas.
- The method is economically profitable, as landfill costs in Norway are high, and landfilling requires longer transport of the masses.

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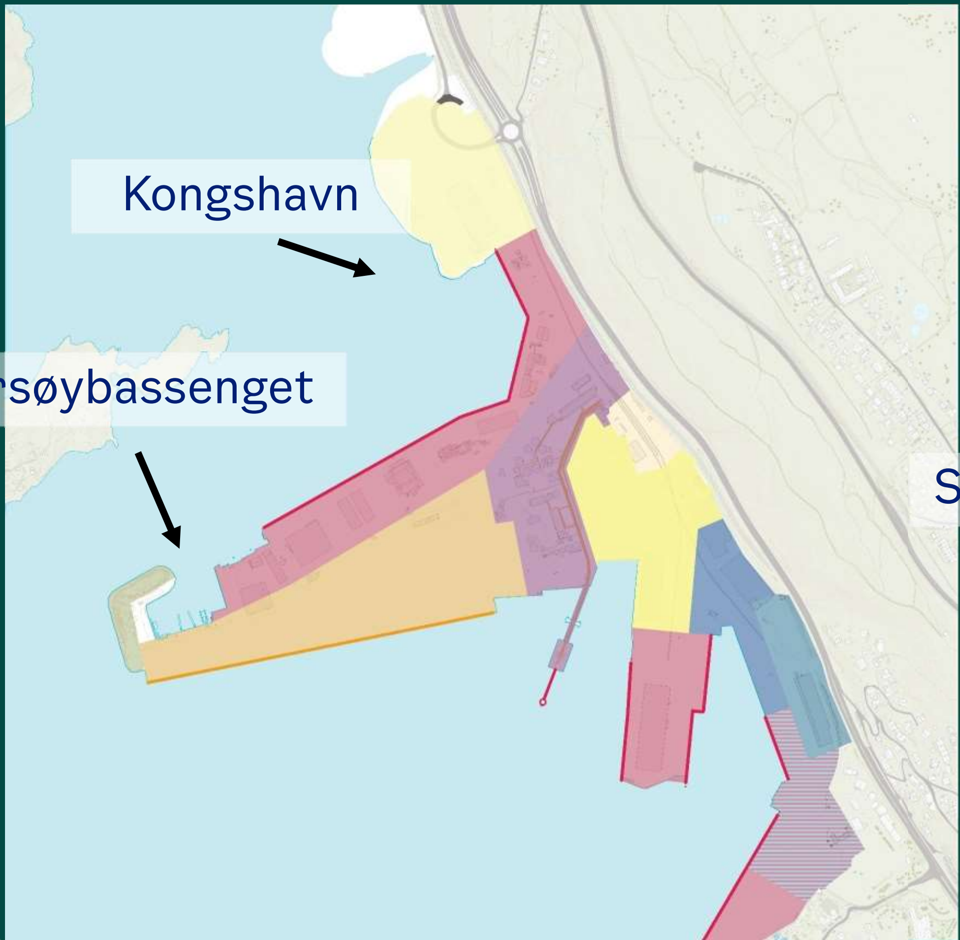

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